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Combined results of searches for first generation leptoquarks

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Abstract

We report on the combination of the searches for first generation scalar leptoquarks performed using 72 $pb^{-1}$of Run II data.
First we combine the results of the searches in two channels: eejj[1] and eνjj[2] are combined obtaining an upper limit on the production cross section as a function of the leptoquark mass and the branching ratio β= Br(LQ$\rightarrow$eq). We then combine the above two channels with the $\nu\nu$jj[3] channel result and obtain a limit better than the individual channels in the low β region (β < 0.2).
By comparison with the theoretical expectations[4] we set lower limits on m(LQ) as a function of β.

Introduction

Searches for pair produced first generation LQ have been performed using the first Run II data in three channels:

- **eejj** – This search gives an upper optimal limit for branching ratio β= Br(LQ$\rightarrow$eq). = 1. The limit obtained with 72pb^{-1} is m(LQ) > 230 GeV/c^2 at 95% CL;
- **e**n**jj** – This search gives the highest optimal limit for a branching ratio β= Br(LQ$\rightarrow$eq). = 0.5. The limit obtained with 72pb^{-1} is m(LQ) > 166 GeV/c^2 at 95% CL).
- nn**jj** – The optimal limit is obtained for β= Br(LQ$\rightarrow$eq). = 0.0 and the CDF results, based on 76pb^{-1} is m(LQ) > 107 GeV/c^2 at 95% CL .

In Figure 1 we present the exclusion regions as function of β obtained from the single channel analysis eejj and eνjj.

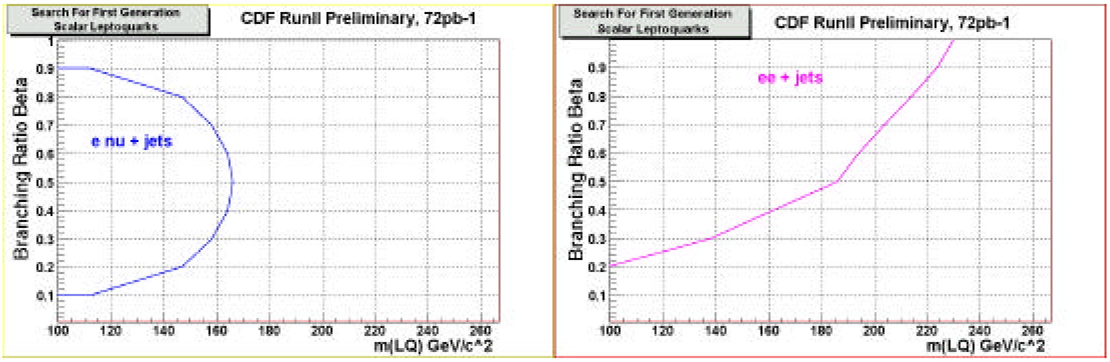

Figure 1 – Exclusion regions as a function of Br(LQ $\rightarrow$ eq) obtained from the single eνjj and eejj channels. The areas at the left of the curves are excluded at 95% CL.

This note presents 2 results: the combination of the 2 channels eejj and eνjj, and the combination of all three possible decay channels. The results are combined using a procedure based on a Bayesian approach[5], which takes into account the correlations in the systematic uncertainties.

Method

To calculate the limits combining all the available leptoquarks decay channels we have used a Bayesian approach. A joint likelihood has been formed from the product of the individual channels likelihood. For each mass we simulated 10K pseudo-experiments, smearing the calculated number of background events and the estimated number of signal events by their respective total uncertainties. The searches in the eejj and eνjj channel use common criteria and sometime apply the same kind of requirements (for example on the tight electron identification) so the uncertainties in the acceptances have been considered completely correlated (which gives the most conservative limit). When calculating the limit combination including also the ννjj channel the uncertainties in the acceptances have been considered uncorrelated.
We want to spend a few words on the technical aspects of the modified bayes[5] program which has been used in the calculation of the combined limit. The program uses a likelihood-based limit procedure and produces a joint likelihood where the likelihood for each channel is multiplied together. At the end one variable for the signal, Nsig, is obtained. To get the limit cross section for channel *i*, one uses the formula:

$$\sigma_{LIM} = N_{LIM}/(\varepsilon_i \times L)$$

where ε_i is the efficiency for the channel in consideration. For more than one channel we use the formula:

$$\sigma_{LIM} = N_{LIM}/(\varepsilon_{average} \times L)$$

where $\varepsilon_{average} = (\beta^2\varepsilon(eejj) + 2\beta(1-\beta)\varepsilon(e\nu jj) + \beta^2\varepsilon(eejj \text{ as } e\nu jj))$ for the 2 channels case and $\varepsilon_{average} = (\beta^2\varepsilon(eejj) + 2\beta(1-\beta)\varepsilon(e\nu jj) + (1-\beta)^2\varepsilon(\nu\nu jj) + \beta^2\varepsilon(eejj \text{ as } e\nu jj)))$ for the three channels case.

For each β value a limit on the expected number of events is returned for each mass. The resulting cross section limit is then compared with the theoretical production cross section for the 2 channels case (see figure 3) and for the 3 channels case (figure 4). In deriving the mass limit we consider the total production cross-section, as the branching ratio is already counted in the average efficiency formula.

Results

The results of the combination for first generation scalar leptoquarks are presented in Figure 2 and Figure 4 , for the 2 cases:

- ee jj and eνjj combination
- eejj, eνjj,$\nu\nu$jj combination

In Figure 3 we report the cross section upper limit compared with the theoretical prediction $\times$ branching ratio as function of the leptoquark mass for different values of β in the case where only two channels are combined. At the intersection point the mass limit is derived.
In Figure 4 we report the same in the case where all three channels were combined. The introduction of the third channel improves the limit at $\beta < 0.2$.

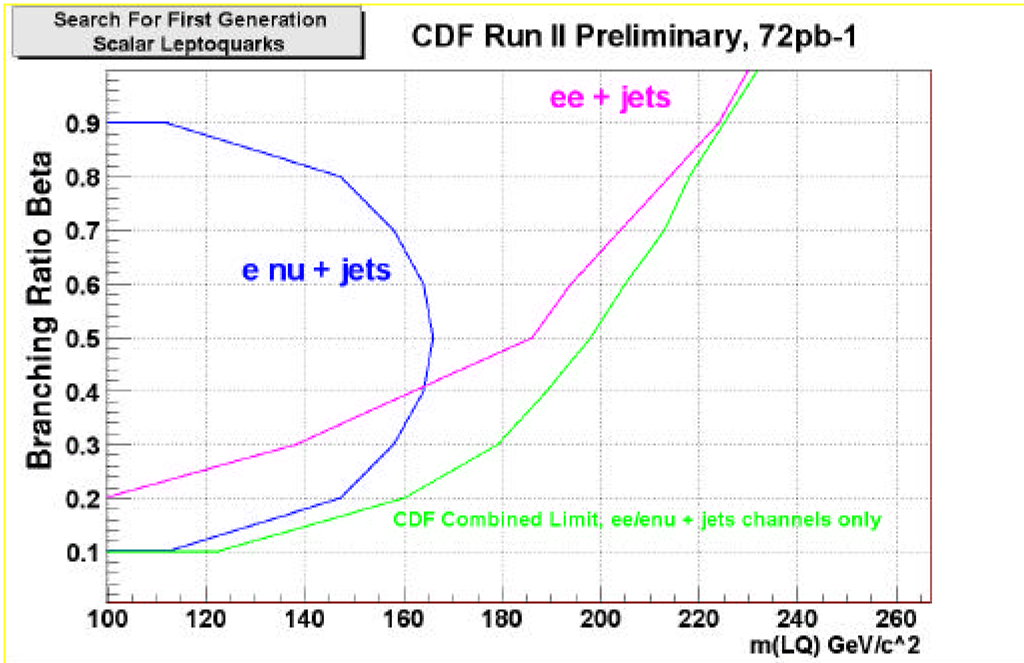

Figure 2 – Exclusion regions as a function of Br(LQ ® eq) obtained from the single e njj and eejj channels, and their combination (green curve). The areas at the left of the curves are excluded at 95%CL.

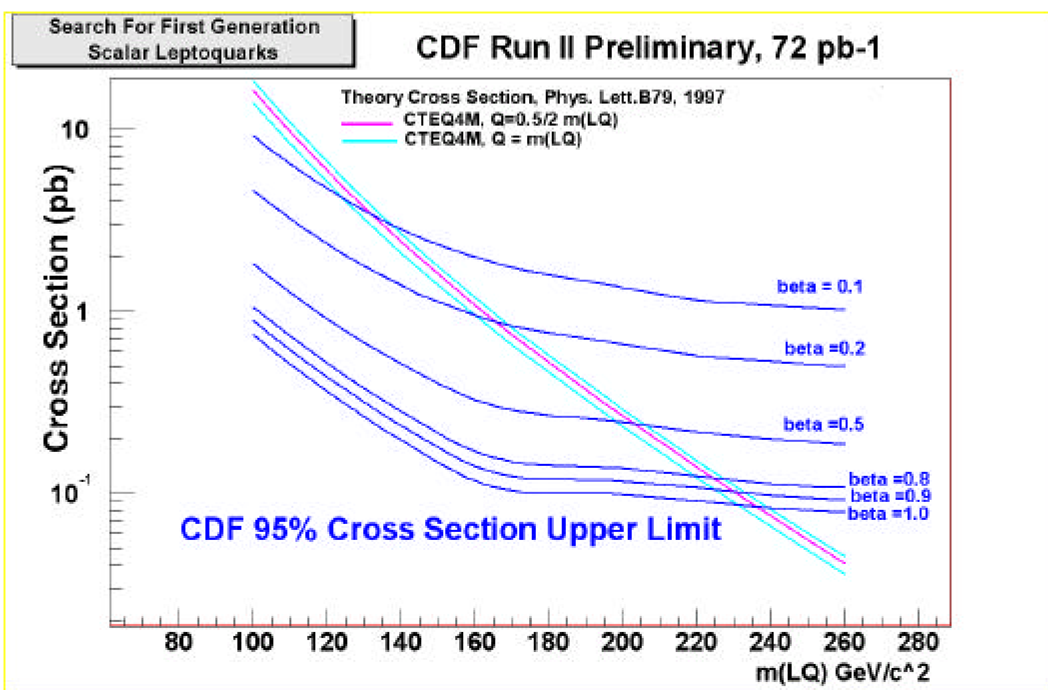

Figure 3 – CDF 95% Upper Limit on the leptoquark cross-section as a function of the leptoquark mass, in the case where eejj and e njj channels are combined. At the intersection with the theoretical prediction an upper limit on the mass is derived.

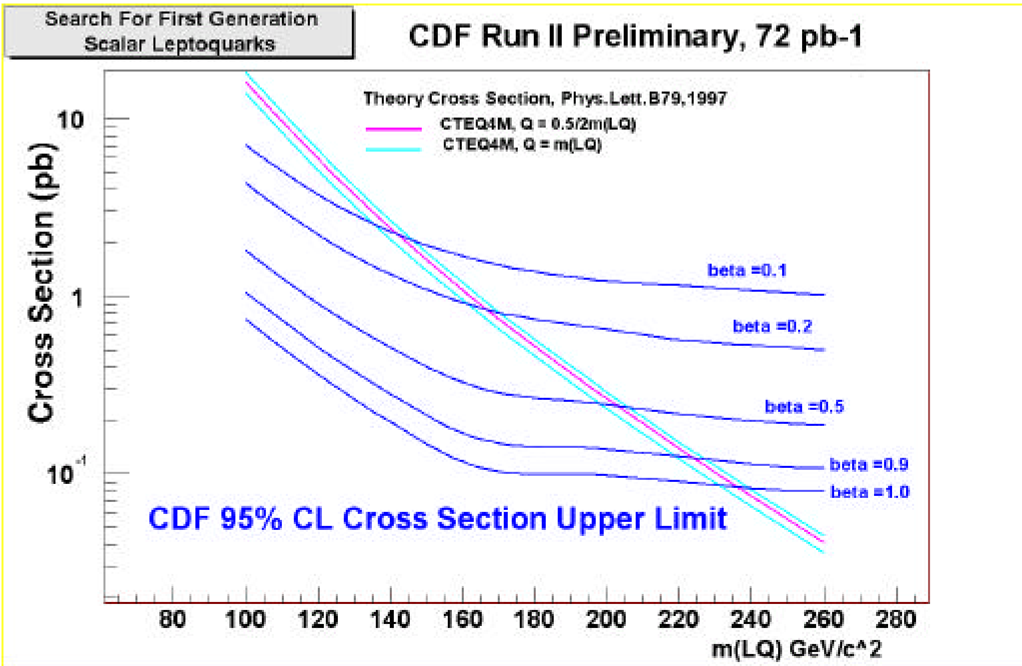

Figure 4 - – CDF 95% Upper Limit on the leptoquark cross section as a function of the leptoquark mass, in the case where eejj, eνjj and ννjj channels are combined. At the intersection with the theoretical prediction an upper limit on the mass is derived.

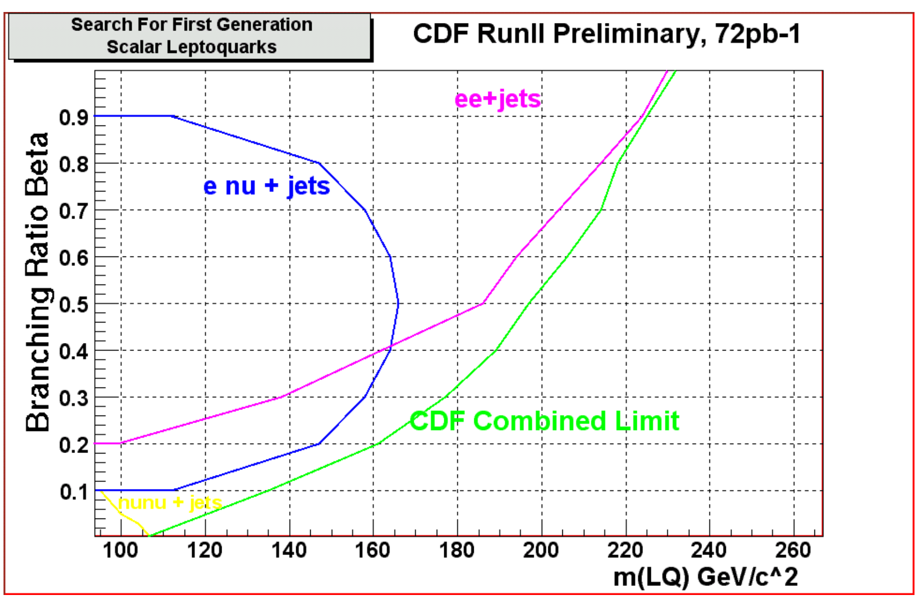

Figure 5 — Exclusion regions as a function of Br(LQ → eq) obtained from the single eνjj and eejj, ννjj channels, and their combination (green curve). The areas at the left of the curves are excluded at 95%CL.

In Table 1 we report the combined 95% CL cross section limits for different LQ masses and for some values of β. The combination is performed also for β= 1, since the eνjj analysis has a non-zero efficiency for di-electron events, when one of the electrons is not in the detector acceptance.

M(LQ) GeV/c^2	β=0.2	β=05	β=1.0
	σ_{95} (pb)	σ_{95} (pb)	σ_{95} (pb)
100	4.5	1.8	0.8
140	1.3	0.5	0.2
160	0.9	0.3	0.12
200	0.7	0.24	0.098
220	0.6	0.22	0.091
240	0.5	0.20	0.083

Table 1 – 95% CL combined cross section limits for different values of b, obtained from the combination of only eejj and e njj channels (case mass = 220, 240 GeV/c^2) and from all three eejj, e njj and nnjj channels (mass < 220 GeV/c^2)

In Table 2 we report the 95% CL upper limit on the leptoquark mass in the case where only 2 channels are combined or all three. As we can see, the limits are of similar magnitude for β > 0.5, while for lower values of β the inclusion of the third channel improves greatly the limit.

β	Mass 95% Upper Limit(GeV/c^2) 3 channels	Mass 95% Upper Limit(GeV/c^2) 2 channels
0.1	135	122
0.2	161	160
0.3	177	179
0.4	189	189
0.5	197	198
0.6	206	205
0.7	214	213
0.8	218	218
0.9	225	225
1.0	232	232

Table 2 – 95%CL mass upper limits for the combination of three channels and two channels.

Conclusions

We have performed the combination of all the CDF searches for first generation scalar letpoquarks using Run II data. The results are presented for the 2 channels eejj and eνjj

combination, and the combination of all three possible decay channels. The results are combined using a procedure based on a Bayesian approach, which takes into account the correlations in the systematic uncertainties.
We set 95% CL lower limit for scalar first generation leptoquarks at 135 GeV/c^2 (β =0.1), 161 GeV/c^2 (β =0.2), 197 GeV/c^2 (β =0.5) and 232 GeV/c^2 (β =1.0).

Acknowledgements

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References

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